A Citywide Analysis of the Utilization of Common Laboratory Tests and Imaging Procedures in ICUs*

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Objective: To identify and discriminate between patient and institutional determinants of investigation costs in the ICU.
Design: Retrospective survey.
Setting: All seven hospitals in the city of Winnipeg, Manitoba, Canada.
Participants: One hundred consecutive admissions to each of 11 ICUs. Two teaching hospitals (TH1 and TH2) each have three units (medical, surgical, and coronary care), the five community hospitals (CHs) have single combined units. TH1 operates an information-based management system.
Measurements: Each admission was categorized as MEDICAL, SURGICAL, or CARDIAC. The frequency and cost of 17 laboratory or imaging procedures were collected for each admission. Demographic data included age, length of ICU stay, APACHE II (acute physiology and chronic health evaluation) score, therapeutic intervention scoring system (TISS) data, and ICU survival. The primary diagnosis on admission and acquisition of significant problems or complications after admission were collected.
Results: Multivariate models revealed that length of stay, TISS score, and acquisition of a problem after ICU admission were strongly associated with increased costs in all categories (p=0.0001). Admission to TH2 was associated with greater costs in all categories (p=0.0001 MEDICAL and CARDIAC; p=0.0016 SURGICAL). Admission to a CH was associated with lower cost for SURGICAL admissions (p=0.0014), but costs at CHs were not significantly lower than at TH1 for MEDICAL (p=0.18) or CARDIAC (p=0.22) admissions.
Conclusions: ICU investigation costs vary significantly between institutions and are not always linked to patient-dependent factors. Acquisition of nosocomial and iatrogenic events during ICU admission increases costs dramatically. Costs are not necessarily greater in teaching hospitals.
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Key words: cost, cost analysis; diagnostic tests; hospital, teaching; hospital, university; intensive care units

Abbreviations: ANOVA=analysis of variance; APACHE=acute physiology and chronic health evaluation; CH=community hospital; LOS=length of stay; MI=myocardial infarction; PAC=pulmonary artery catheter; TH1=teaching hospital 1; TH2=teaching hospital 2; TISS=therapeutic intervention scoring system

In the last decade, most comparative ICU performance evaluations have concentrated on survival outcomes using predictive models.[1-4] Despite the expensive nature of critical care, there have been few attempts to compare and characterize patterns of test utilization and costs between ICUs.[4,5] More data are available on the patterns of testing and resource consumption in single institutions.[6-11] Because of limitations in costing models used in previous studies, there is little information with respect to identifying determinants of laboratory and imaging utilization across institutions. We performed a retrospective analysis of 100 consecutive ICU admissions at each of the 11 adult ICUs in the city of Winnipeg to identify and discriminate between patient-based and institutional determinants for ordering common laboratory and imaging procedures.

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Materials and Methods

Hospital Descriptions

Under the auspices of a provincial ICU review committee appointed by the Ministry of Health, cooperation was obtained

from the medical vice presidents and unit directors of the two university-affiliated, tertiary care hospitals and the five community hospitals in the city. The tertiary care hospitals have separate medical ICUs, surgical ICUs, and coronary care units. These function as closed units (*ie*, patient care is directed by full-time assigned academic intensivists and cardiologists), have full-time medical directors, and are involved in the training of subspecialty critical care and cardiology residents. Only the tertiary care hospitals have dialysis facilities, and all cardiac and neurosurgery is performed in these centers. The community hospitals have single open units that admit medical, surgical, and coronary care patients. Patient care is directed by private practice subspecialists and generalists. Off-hour physician coverage is provided by emergency department or house medical officers.

Study Subjects

Data were retrospectively obtained by study nurses from the charts of 100 consecutive admissions to each of the 11 units beginning September 1, 1992. Fifteen percent of the charts completed by each nurse were reviewed by the study coordinator for accuracy and completeness. Study nurses retrospectively determined the primary reason for ICU admission, and collected up to five additional admission diagnoses. Potentially life-threatening iatrogenic, nosocomial, or new disease processes developing after ICU admission were recorded as acquired diagnoses. All data were entered into an ICU research and resource utilization computerized database (Critical Care Manager 2.1; TMS Inc; Chelmsford, Ontario).

To facilitate comparison, the 11 study units were separated into three groups. One teaching hospital (TH1; n=300) operates a long-standing information-based management program directed toward improving quality and efficiency of care in ICU.[11] The other teaching hospital (TH2; n=300) has no similar program in operation. The five community hospitals (CHs; n=500) provide comparable levels of care, share common administrative features, and have no ongoing extensive resource management programs.

Diagnostic Categories

Each admission was categorized as MEDICAL, SURGICAL, or CARDIAC. Patients admitted from recovery or operating rooms or following trauma, burns, or upper GI bleeding were categorized as SURGICAL. CARDIAC admissions included patients with myocardial infarctions, acute rhythm disturbances, unstable angina, chest pain, congestive heart failure, and patients admitted following coronary angiography or angioplasty. MEDICAL admissions included patients with cardiogenic shock, those resuscitated from cardiopulmonary arrest, those suffering from multiple organ failure, or problems that did not fall into SURGICAL or CARDIAC categories. A committee including two ICU physicians not involved in data collection assigned categories with majority opinion ruling in disputed cases.

CARDIAC admissions were grouped into three subcategories: myocardial infarction (MI), no MI, and procedural (admitted for angiography or angioplasty). The SURGICAL admissions were subcategorized by type of procedure: thoracic/cardiac; abdominal/urologic/gynecologic; vascular; peripheral (orthopedic, head and neck, breast); and neurosurgical. MEDICAL subcategories were postcardiac arrest, pulmonary admission (pneumonia, pulmonary embolus, etc), overdose/poisoning, septic shock, and other.

Outcome Variables

Frequency and cumulative costs of 17 laboratory and imaging procedures were collected for each ICU admission. These investigations included the following: biochemical tests (arterial blood gas, potassium, glucose, creatine kinase, creatine kinase MB, CBC count, CBC with manual differential, creatinine, magnesium, prothrombin/partial thromboplastin time, aspartate serum transferase); microbiologic procedures (cultures of blood, sputum, and urine); imaging procedures (chest radiograph and abdominal ultrasound); and ECGs. This group of investigations previously accounted for more than 60% of all diagnostic costs in 6,000 consecutive ICU admissions at TH1. A previously described cost list derived at TH1 was updated and utilized for cost calculations in all units.[11]

The cost list was generated by an independent hospital finance committee in cooperation with individual laboratory departments. Calculations were based on actual labor, materials, supplies, and equipment costs incurred by the hospital. These included nursing time at the bedside to collect the specimens, technician time to perform analysis, and supplies in the ICU and laboratory. We did not include any allowance for maintenance of equipment or capital equipment cost in these calculations. The costs used are shown in Appendix 1.

Covariates

Demographic data included age, sex, date and time of ICU admission and discharge, and ICU mortality. Worst APACHE II (acute physiology and chronic health evaluation II)[12] score during the first 24 h of ICU admission and a daily therapeutic intervention scoring system (TISS) score[13,14] for the first 5 days of ICU were collected. The day 1 TISS scores were compared separately and TISS data were used to determine incidence of the following interventions: arterial line insertion, mechanical ventilation, pulmonary artery catheter (PAC) insertion, dialysis, and infusion of vasoactive drugs.

The recorded acquired diagnoses were reviewed. Patients with one or more significant acquired diagnoses were coded as a separate category. Only iatrogenic, nosocomial, or disease processes not present at the time of admission were included. Significant acquired diagnoses included such events as pneumonia, pulmonary embolus, pneumothorax, GI hemorrhage, MI, rhythm disturbance, cardiogenic shock, congestive heart failure, central venous or arterial catheter complications, cerebrovascular events, and septic shock.

Statistical Analysis

Analysis of variance (ANOVA) was used for continuous variables and frequency data were compared using χ^2. Multiple comparisons with Bonferroni correction followed a significant global test. Comparisons were conducted only within admission categories (*ie*, SURGICAL admissions at TH1 were not compared with CARDIAC admissions at CH) and p value for significance after Bonferroni correction was $p<0.015$. An all-possible regression analysis with cost as the dependent variable was performed for each category of admission (MEDICAL, SURGICAL, CARDIAC) using software (SAS; SAS Institute; Cary, NC) with $p<0.05$ for significance. Length of stay (LOS), arterial line insertion, PAC placement, and vasoactive drug use were tested for interaction with institution using dummy variables. The baseline hospital used for comparisons was TH1.

Results

Demographic variables and distribution within diagnostic categories are compared among the three

locations in Table 1. Mean APACHE II scores within each category (MEDICAL; SURGICAL; CARDIAC) did not differ significantly among locations. Day 1 TISS scores were significantly lower at CH in the SURGICAL category ($p<0.0001$ vs both TH1 and TH2) and in the MEDICAL category ($p=0.003$ vs TH1; $p=0.0001$ vs TH2). No significant difference in LOS was found among locations within any of the three categories, although there was a trend toward longer LOS in the CARDIAC group at CH ($p=0.05$ compared with TH1). A difference in average age was present in the SURGICAL category between CH and TH1 ($p=0.03$), but this did not achieve significance after Bonferroni correction. Distribution of admissions among the three major diagnostic categories was similar in both teaching hospitals; however, there was a preponderance of CARDIAC admissions at the CHs (51%). Mechanical ventilation, arterial lines, and PACs were used or required more frequently in TH1 and TH2 than in CHs.

Average cost per admission and cost per ICU day of laboratory tests and imaging procedures are shown in Figure 1 for each category in the three locations. These costs are not adjusted for differences in acuity of illness. Costs per admission for MEDICAL patients are significantly greater at TH2 ($604±768) than at the other locations ($p=0.002$ for TH2 vs TH1; $p=0.0002$ for TH2 vs CH). Unadjusted costs for SURGICAL admissions were lower at the CHs ($p=0.01$ CH vs TH1; $p=0.001$ CH vs TH2). Mean costs per ICU day for SURGICAL admissions were lower in TH1 than in TH2 ($p=0.0001$). Although cost per ICU day for CARDIAC admissions was lowest at TH1, statistical significance was not achieved. Unadjusted average cost per day for MEDICAL admissions was also lowest at TH1, but was not statistically significant.

Table 2 shows the results of a univariate analysis for the three categories of admissions. Location (TH1, TH2, or CH) was associated with cost in all diagnostic categories. Acquired diagnosis, APACHE II score, TISS score, PAC insertion, and mechanical ventilation were also significant predictors of costs in all three categories. Separate all-subset multiple regressions were performed to examine the influence of location when other factors were accounted for. Mechanical ventilation, pulmonary artery catheterization, and arterial line insertion were all factors associated with location. We elected to keep location in the model and allowed these other factors to be eliminated. The final model is given by the following equation: cost ($) $=\text{intercept}+\Sigma\beta_i X_i$ where β_i is the coefficient and X_i the predictor variable. TH1 was used as the baseline for all comparisons in the models. The final regression equations for the three patient categories are described in Table 3. The model for 272 MEDICAL admissions accounts for 79% of the variation in cost within the group. The significant factors associated with increased cost other than overall LOS included the presence of an acquired diagnosis ($p=0.0001$) and admission to TH2 ($p=0.0001$). Admission to TH1 was associated with lower costs than CH admission, but this did not achieve statistical significance ($p=0.18$). There was a small but significant relationship between increasing age and lower costs among MEDICAL patients. Increased TISS scores were also associated with increased cost ($p=0.0001$). None of the MEDICAL diagnostic subcategories was a significant predictor of costs.

The final regression model for the 337 SURGICAL admissions is also described in Table 3 and accounts for 85% of the cost variability within this group. Again, the presence of an acquired diagnosis greatly influenced cost ($p=0.0001$). Admission to TH2 predicts higher costs for laboratory testing than admission to TH1 ($p=0.0016$). Lower laboratory

Table 1–*Demographic, Diagnostic Category, and Intervention Data at Teaching Hospitals and CHs**

	MEDICAL			SURGICAL			CARDIAC		
Category	TH1	TH2	CH	TH1	TH2	CH	TH1	TH2	CH
No.	89	71	112	98	108	131	113	121	257
Mean APACHE II	21.4±9.9	22.5±9.1	20.7±10.3	16.7±7.8	15.4±5.5	14.8±7.2	12.0±7.0	11.3±6.4	12.0±6.0
Mean TISS score	28.6±13.2[†]	30.5±10.7[‡]	22.8±11.1	39.6±13.4	42.7±11.9	24.6±8.1[§]	15.8±6.6	17.9±9.4	16.1±6.7
Mean LOS, d	4.8±7.9	4.9±6.0	3.9±5.4	3.6±7.0	2.6±2.7	2.8±5.9	1.9±1.8	2.4±2.5	4.0±3.5
Age, y	57.1±19.9	58.2±19.7	62.7±17.8	61.2±12.8	64.5±12.8	68.1±14.9	66.3±12.9	67.7±10.6	67.9±12.0
Ventilated, No. (%)	61 (69)	51 (72)	43 (38)	71 (72)	92 (85)	42 (32)	13 (12)	13 (11)	14 (5)
Arterial line, No. (%)	72 (81)	59 (83)	51 (46)	94 (96)	101 (94)	91 (69)	17 (15)	20 (17)	19 (7)
PAC, No. (%)	25 (28)	22 (31)	17 (15)	53 (54)	74 (69)	19 (15)	5 (4)	8 (7)	2 (1)

*Results are mean±SD or No. (%); p assessed by ANOVA (Bonferroni adjusted $p<0.015$).
[†] $p=0.003$, TH1 vs CH.
[‡] $p=0.0001$, TH2 vs CH.
[§] $p=0.0001$, CH vs TH1 and CH vs TH2.

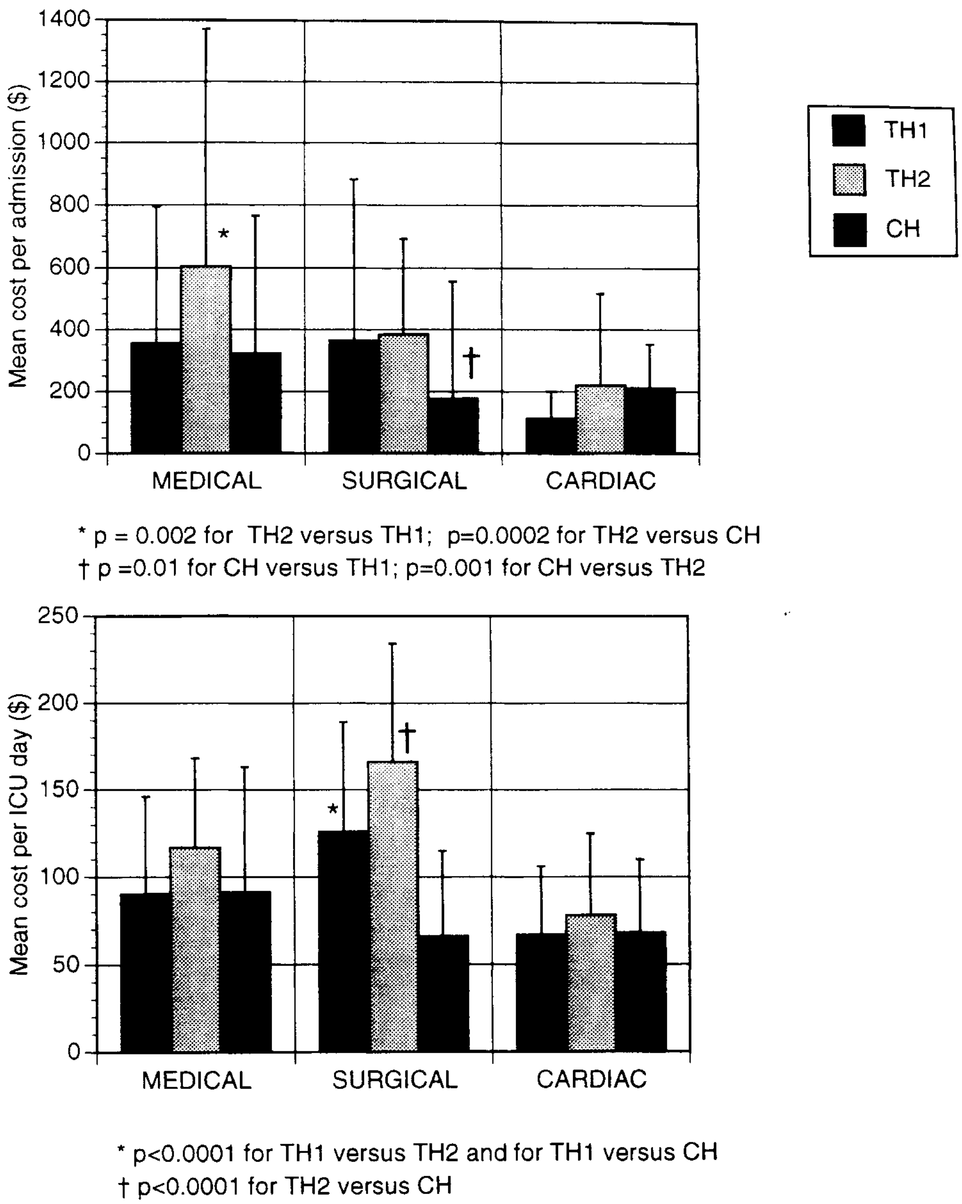

FIGURE 1. Average unadjusted cost of testing per admission (*top*) and per ICU day (*bottom*) in Canadian dollars for MEDICAL, SURGICAL, and CARDIAC patients admitted to each location. Values are mean±SD. p values from ANOVA.

costs are associated with admission to CH (p=0.0014). Positive associations with cost were identified for both day 1 TISS and APACHE II scores. Age was not a significant predictor. No SURGICAL diagnostic subcategories were predictive of increased costs.

Table 3 also contains data for 491 CARDIAC admissions. The final model accounts for 51% of the variability in this group. The presence of an acquired diagnosis was the greatest determinant of increased cost (p=0.0001). Patients suffering MI emerged as a more expensive diagnostic subgroup (p=0.04) and patients admitted only for angiography or postangioplasty were less expensive (p=0.003). Admission to TH2 was associated with higher costs (p=0.0001). Although mean costs were lower at TH1, no significant differences in cost were noted between TH1 and the CHs (p=0.2). TISS score was associated with increased cost (p=0.0001); however, neither age nor APACHE II score was correlated with expenditure in this group. Use of more than one vasoactive drug was associated with increased costs, but this was not statistically significant (p=0.053).

Figure 2 summarizes the relationships found in

Table 2—*Significance Levels of Factors Examined in Univariate Analysis for Cost in the Three Categories of ICU Admission*

Factor	p Values		
	MEDICAL	SURGICAL	CARDIAC
Location	0.002	0.0001	0.0001
Subcategory	0.0001	0.0014	0.0001
LOS, d	0.0001	0.0001	0.0001
Age, y	0.034	NS*	NS
APACHE II	0.0196	0.0001	0.0001
TISS	0.0001	0.0001	0.0001
Acquired diagnosis	0.0124	0.0347	0.0005
Arterial line	0.0001	NS	0.0026
PAC	0.0001	0.0001	0.0046
Ventilator	0.0057	0.0005	0.0025
Single vasoactive drug	0.0112	NS	0.0015
Two or more vasoactive drugs	NS	0.0007	NS

*NS=not significant.

the regression models between site of admission and predicted costs. Admission to TH2 was clearly associated with higher costs than TH1 admission in all categories (p=0.0001 for MEDICAL and CARDIAC; p=0.0016 for SURGICAL). Admission to CH was associated with higher predicted costs than TH1 admission in MEDICAL and CARDIAC categories but did not achieve statistical significance. In

Table 3—*Final Cost Regression Models for Predicted Laboratory Cost in Each Admission Category Using TH1 as the Baseline (in Canadian Dollars)**

MEDICAL: n=272 r^2 for model=0.79

Predicted cost ($)=−41.7+65.3 (LOS)+6.1 (TISS)+273.3 (ACQUIRED)+218.5 (TH2)+51.1 (CH)−1.9 (AGE)

p=0.0001 for all variables except: Intercept p=0.5; CH admission p=0.1831; AGE p=0.0261

SURGICAL: n=337 r^2 for model=0.85

Predicted cost ($)=−103.4+62.7 (LOS)+3.9 (TISS)+154.9 (ACQUIRED)+73.0 (TH2)−80.7 (CH)+4.4 (APACHE)

p=0.0001 for all variables except: Intercept p=0.0072; TH2 admission p=0.0016; CH admission p=0.0014; APACHE p=0.0017

CARDIAC: n=491 r^2 for model=0.51

Predicted cost ($)=−39.6+26.7 (LOS)+6.0 (TISS)+183.5 (ACQUIRED)+79.2 (TH2)+19.5 (CH)+26.6 (MI)−81.2 (ANGIO)+64.6 (VASO)

p=0.0001 for all variables except: Intercept p=0.04; CH admission p=0.2207; MI p=0.0445; ANGIO p=0.0026; VASO p=0.0533

*Where LOS=LOS in ICU (per day); TISS=TISS score (per day 1 point); ACQUIRED=presence of a significant acquired diagnosis (yes=1 or no=0); TH2=admission to TH2 (yes=1 or no=0); CH=admission to a CH (yes=1 or no=0); AGE=age in years (per year); APACHE=APACHE score (per point); MI=admission with documented MI (yes=1 or no=0); ANGIO=admission for angiogram or angioplasty (yes=1 or no=0); and VASO=use of two or more vasoactive drugs in ICU (yes=1 or no=0).

SURGICAL admissions, CH costs were less than TH1 (p=0.0014). Figure 2 also illustrates the considerable effect of acquisition of a diagnosis or complication after ICU admission in all categories (p=0.0001).

There was a 9.6% incidence of acquired diagnoses in the CH group, compared with a 5% incidence at TH1 (p=0.022; odds ratio 2.02 [1.11, 3.67, 95% confidence interval]). Eleven diagnoses accounted for 90% (54/60) of the patients experiencing an acquired event after admission. The distribution of these diagnoses is described in Table 4.

Mortality for MEDICAL admissions was similar at all three locations and no statistically significant differences among locations were noted. There were 22 deaths (24.7%) at TH1, 17 (23.9%) at TH2, and 29 (25.9%) at CH for MEDICAL admissions. Similar nonsignificant differences were noted for CARDIAC admissions with four deaths at TH1 (3.5%), three (2.5%) at TH2, and 11 (4.3%) at CH. A significant mortality difference was found for SURGICAL admissions. TH1 had 21 deaths (21.4%) in this category. This was significantly higher (p=0.0016) than at TH2 where only six deaths were noted (5.6%), and higher than at CH where only two SURGICAL patients died (1.5%; p=0.0001). The deaths at TH1 included the following: four emergency neurosurgical cases; two brain-dead patients admitted for organ donation; three cardiac surgery patients; one patient with major burn; and one multiple trauma patient. Four of the remaining cases involved thoracic or abdominal aortic vascular repairs and the remaining six were abdominal cases. SURGICAL deaths at TH2 included two abdominal cases, one coarctation of the aorta, one abdominal aortic aneurysm, one thoracotomy, and one craniotomy for head injury. Both deaths at CH were abdominal cases.

Discussion

Our study demonstrated that cost of investigations during ICU admission varies significantly between institutions and that institutionally linked factors may be as or more important than patient-dependent factors in determining cost.

Before discussing these factors, it is important to describe the limitations of this study. Only 100 admissions were included from each of the study units, and therefore important interunit differences might not have been detected due to limited sample size. Our ability to compare costs among admissions in the SURGICAL category at the three locations is limited by clear differences in diagnostic mix between the teaching and CHs. The lower costs for

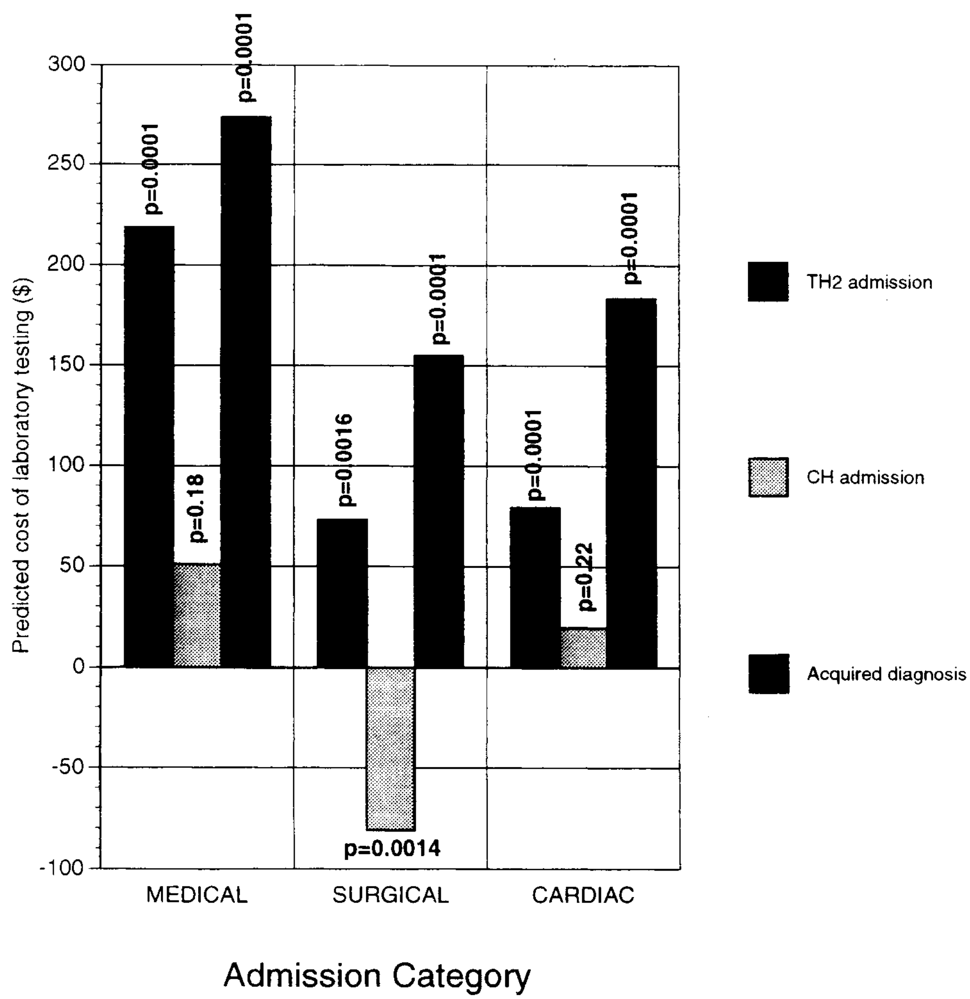

FIGURE 2. Cost coefficients from regression models for laboratory testing costs predicted if patient admitted to TH2 or CH instead of TH1, and cost coefficients for each category if there was an acquired diagnosis. All costs are in Canadian dollars. p values are from regression models.

SURGICAL admissions at CH might relate to these units functioning as overnight recovery areas for relatively routine postoperative patients. These hospitals do not have cardiac or neurosurgical admissions and few trauma cases, which represent the majority of teaching hospital SURGICAL admissions.

Our cost model is based on the frequency of commonly performed laboratory tests and imaging procedures. Similar cost models have been reported previously.[7] The 17 specific items we used were identified from a comprehensive computerized ICU database of more than 6,000 consecutive ICU admissions at TH1 and account for approximately 60% of all laboratory and imaging costs at this hospital. We used costs rather than charges in this study,[15] but applied a standard cost list to all hospitals. In other studies of ICU costs, the laboratory and imaging

Table 4—***Acquired Diagnoses at All Locations***

	TH1	TH2	CH
Total admissions	300	300	500
No. (%) with any acquired	15 (5)	25 (8)	48 (9.6)
Common acquired diagnoses occurring in more than two patients			
Rhythm disturbance	4	7	13
Pneumonia	1	3	11
Line complication	3	5	2
Cerebrovascular accident	2	1	1
ARDS	1	2	1
Septic shock	1	1	2
MI	0	2	2
Acute renal failure	0	1	2
GI bleed*	1	0	2
Congestive heart failure	0	0	3
Acute surgical procedure	1	2	0

*GI bleed includes upper and lower GI bleeding.

component has accounted for 14 to 23% of total ICU costs or charges.[16-18] Clearly there are other significant determinants of ICU cost (pharmaceuticals, supplies, and labor) that were not included in our data collection. Several previous studies have used alternate costing models (weighted LOS or TISS as cost equivalents) to make comparisons between institutions,[2,5,8,10] and our regression analysis indicates a clear correlation between our costs and both LOS and level of intervention assessed by day 1 TISS score. Longer admissions should be associated with more testing and higher costs. Unfortunately, cost models based on LOS or TISS scores are incapable of detecting differences in resource utilization due to institutional-specific practices affecting efficiency or cost effectiveness of care. We believe that our costing model is more sensitive for measuring such differences.

Only a few patient-specific admission characteristics were found to correlate with cost. Within the CARDIAC group, costs were greater in admissions with MIs. This has been reported previously.[19] None of the diagnoses or procedurally based subcategories for MEDICAL or SURGICAL admissions were predictive of cost. Age was only a weak negative predictor of cost in the MEDICAL group and did not emerge in the final regression models for SURGICAL or CARDIAC admissions. Worst APACHE II score in the first 24 h correlated with cost in SURGICAL admissions but failed to emerge as a significant factor in the other two groups. This suggests that patient-based demographic or diagnostic variables, and levels of acuity assessed by admission APACHE II scores are not major determinants of laboratory and imaging costs.

Levels of intervention as assessed by first-day TISS score correlated with cost in all three groups. Possible interactions between TISS and location were not examined in the analysis. The observation that TISS scores were lower at TH1 vs TH2 despite higher mean acuity levels at TH1 (Table 1) suggests that location may be an independent determinant of level of intervention.

Our data demonstrate that there are cost differences between the two teaching hospitals in Winnipeg that cannot be explained by case mix or acuity. In all three categories of admission, patients admitted to TH2 had more expenses than patients admitted to TH1. The ICUs in these two institutions have very similar staffing and administrative systems. In fact, many of the attending physicians and house staff rotate between units in both institutions. However, TH1 has developed and implemented a longstanding information-based management system directed toward improving quality of care and increasing efficiency of resource utilization. Prior to the study period, various changes had been implemented to reduce needless consumption of pharmaceuticals, tests, and monitoring at TH1.[11] These included ongoing inservicing programs and the development of algorithms for both nurses and physicians to effect more rational use of resources. Specific measures were taken to reduce ECGs, chest radiographs, blood gas studies, and electrolyte determination. This process has been widely supported by nursing staff who have adopted the approach and altered their practice. The use of an automated information system combined with this management approach has resulted in maintenance of decreased levels of testing as outlined in our previous report.[11]

It is likely that the success of this program accounts for much of the cost difference identified in this study between the two teaching institutions. A similar approach is not used at TH2. There is no cooperative management structure involving all critical care team members. Several protocols exist within the surgical ICU that mandate frequent laboratory and imaging tests even if no abnormality is expected. Similar protocols exist in the coronary care unit for ECGs and cardiac enzymes. Nursing staff have not altered their routine and occasional efforts to transfer algorithms or approaches from TH1 have not been successful.

It is generally accepted that costs at teaching hospitals are greater than nonteaching hospitals, and increased laboratory and imaging use has been reported in teaching hospitals.[20] This has been linked to the educational process resulting in greater resource use and longer LOS,[21-23] while others believe it is due to differences in severity of illness.[24,25] Within the admission categories where diagnostic mix was comparable (MEDICAL and CARDIAC), adjusted costs were equivalent or lower at TH1 than at the CHs. There are several possible explanations for this. It is likely that observed differences in patterns of utilizing tests and imaging procedures between ICUs are influenced by differences in existing written policies and algorithms. When such management policies are absent, rituals and routines may develop among both bedside nurses and ICU physicians which drive the frequency of testing and monitoring procedures. We did not specifically tabulate existing unit policies in this study, but clear patterns of testing emerged in some units that were absent in others (*eg*, daily chest radiographs, daily ECG, and serum magnesium determination whenever electrolytes were measured). Increased tendency to use tests and imaging procedures for MEDICAL and CARDIAC patients in the CH setting may be partly attributed to the reduced opportunity to examine and evaluate patients on-site by physicians

who are obligated to office practices and clinics while assuming care for ICU patients.

Higher costs would be justified if they were associated with better outcomes. Mortality was examined as an outcome measure using logistic regressions in each diagnostic category after the cost analysis was performed. No significant relationship between location and mortality was found in MEDICAL and CARDIAC admissions. Mortality in SURGICAL admissions was lower at TH2 and CH (odds ratio 0.22, p=0.01 for TH2; odds ratio 0.08, p=0.008 for CH). There were population differences among the three locations that account for these mortality differences in the SURGICAL population. TH1 is the trauma center and admits multiple trauma, high-risk general surgery, and emergency neurosurgery patients. This hospital is also the burn center for the province and does most of the organ harvesting for transplantation. Two of the SURGICAL deaths at TH1 were brain-dead organ donors, and there was one patient with major burns and one patient with multiple trauma. None of these patients could have been admitted to any of the other hospitals. TH2 admits predominantly cardiac surgical cases that have a low ICU mortality. As discussed previously, no cardiac or neurosurgical procedures, and few high-risk general surgical or multiple trauma patients were admitted to CH.

The CHs had the highest frequency of acquired diagnoses. This is difficult to explain since mean APACHE II scores within diagnostic categories were similar at all locations, and CH admissions had comparatively low levels of intervention as assessed by day 1 TISS score, with less use of mechanical ventilation or invasive monitoring. Acquisition of a nosocomial diagnosis or complication following admission was clearly predictive of increased admission costs in all three diagnostic groups. A more detailed prospective observational study with greater emphasis on adverse events and outcome would be necessary to confirm the significance of this finding and design and test remedial interventions.

In summary, our study indicates that there are differences in the patterns of laboratory testing and cost among the ICUs in our city that are unrelated to patient demographics or admission diagnoses. Our data demonstrate that much of the cost difference is determined by institutionally linked factors that may relate to local practices such as isolated development of routines for the ordering of tests and investigations, and differences in the incidence of complications or adverse events. Finally, our study demonstrates that in terms of utilization of tests and imaging procedures, tertiary care teaching hospital ICUs can be as inexpensive as CH units with application of information-based management techniques.

Appendix 1: Costs of the Laboratory and Imaging Tests in Canadian Dollars*

Test	Cost per Test, $
Abdominal ultrasound	180.00
Chest radiograph	29.00
ECG	24.17
Blood culture	20.00
Sputum culture	14.00
CBC, differential	10.52
Creatine kinase MB	8.81
Creatine kinase	6.03
Urine culture	6.00
CBC	4.34
Arterial blood gas	3.73
PT/PTT	3.68
Magnesium	3.03
Potassium	1.28
Glucose	1.24
Creatinine	1.18
AST	0.94

*Costs based on actual labor, materials, supplies, and equipment costs incurred by the hospital. They include nursing time at the bedside to collect specimens and technician time to perform analysis. PT/PTT=prothrombin/partial thromboplastin time; AST=aspartate serum transferase.

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